

**Computer Multimedia in the Development of Interactive Courseware:
The Cornell University Soil and Water Management Learning Module**

A Thesis

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by

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ABSTRACT

The thesis project consists of an interactive multimedia computer software program, designed to help teach a course title, college-level semester course in soil and water management (Soil and Water Management, offered at Cornell University, Department of Soil, Crop, and Atmospheric Sciences course number 321, 4 credit-hours).

The software was authored in Macromedia® Director® 6.5. Original artwork includes computer graphics some of which are sequenced to create animations that illustrate key concepts of the subject material. Text and photographs and/or illustrations also support the subject material.

BIOGRAPHICAL SKETCH

The author was born in Oneonta, New York, in 1971. She graduated from Oneonta High School as Salutatorian of the Class of 1988 after completing high school in three years.

At Cornell University, she majored in biological sciences, obtaining her Bachelor of Science degree in May 1992. In December 1995, she completed a Master of Science degree in Soil Science, also at Cornell University, under the direction of Harold van Es. Immediately after completing her MS, she took a job in Madras, Oregon, working as a full-time faculty research assistant at one of Oregon State University's branch agricultural experiment stations, the Central Oregon Agricultural Research Center. In July 1997, she quit her position at COARC to move back to upstate New York in preparation for enrollment in the Master of Fine Arts program in medical illustration at the Rochester Institute of Technology.

While positively appreciative of the medical sciences and medical illustration, she chose to make soil and water management the topic of her thesis project because it would be very appropriate to her background while providing interesting experience in visual communication, graphic design, and interactive computer multimedia programming. The result is a unique culmination of her efforts and experiences at both Cornell University and Rochester Institute of Technology.

In the future, the author would like to be involved in the production of educational CD-ROM titles, especially those that teach science to general audiences.

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Also I would like make special thanks to professors whose specific courses particularly helped my development: Glen Hintz (2D Animation, my first exposure to Director); Steve Kurtz (Programming for Digital Multimedia); and Roger Remington (Graduate Graphic Design).

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JUSTIFICATION

There is great potential for the application of computer graphics in science education. Such technology is clearly well-exploited for entertainment, including the motion picture and the computer gaming industries presumably due to the more immediate and lucrative rewards involved in those areas. However, computers are more and more a standard in the classroom at all levels, and classroom technologies, however lagging, are continually upgrading. Because computer graphics can include animations as well as realistic three-dimensional forms, they have the potential to be uniquely valuable teaching tools, especially for scientific concepts which require the understanding of events in sequence and/or in three-dimensions. Finally, unlike conventional movies, computers may be programmed for interactivity. User feedback, the possibility of customization for teacher or student use, and use control over navigation are a few examples of interactivity the computer platform readily provides.

Multimedia as a Teaching Aid

In the lecture hall, such software may be used to present materials to an audience (projected via the appropriate hardware equipment which is currently available, and is becoming increasingly affordable). Depending on how the software is customized, the teacher may control the display text, graphics, audio, and animations, all out of one single software program which may be easily contained on a single CD-ROM and conveyed via a conventional laptop computer with a projector apparatus.

Multimedia as a Learning Aid

Individually or in small study groups, students may access the same software on CD via either IBM-PC or Macintosh computers at home or within a campus computing

facility. Alternatively, the software may be installed via a local area network (LAN) or on individual computer hard drives for student use. The nature of the electronic media allows the material to be easily available and readily duplicated, giving each student exact copies of all course materials, which may include video, audio, photos, illustrations, animations, and text, at no loss of resolution of quality from the original, and in the portable and durable form of a CD-ROM.

The Versatility of Computer Multimedia

Custom programming allows the development of user features/options such as

- the ability to print lecture outlines to take to class
- self-quiz modes
- self- or auto-paced revelation of information (as a lecturing or study aid)
- glossary and index with search features
- active links to Internet sites

MATERIALS AND METHODS

I used a variety of standard and readily-available computer hardware and software products. Hardware used included flatbed scanner (for digitizing images), IBM PC and Macintosh (8600, 9600 and G3 PPC) computers. Computer software included Macromedia® Director® 6.0, 6.5 and 7.0 (authoring software), Adobe Photoshop® 4.0 and 5.0 (for creating and editing raster graphics), Adobe Illustrator® 7.0 (for creating and editing vector-based graphics),

Director® was chosen as the authoring software because of its capacity to produce programs that are self-running, executables (“Projectors”) that may be readily converted into cross-platform versions (thus making the product available for use on either IBM PC or Macintosh computers). The minimum system playback requirements are not excessively demanding, making the product reasonably accessible for general use. Specifically the product is planned to have the following minimum requirements:

- Macintosh: 68020 or faster processor; System 7.0 or higher; at least 8 MB RAM
- IBM: 386/33 or faster; Windows 3.1, NT, 95, or higher; at least 8 MB RAM

It is anticipated that additional hardware (such as VCR and slide scanner) and software (Adobe Premier® for digitizing video, and Adobe Acrobat® for the creation of printer-ready materials in PDF format) may be used in the further development of the project.

PROJECT DESCRIPTION: SUBJECT MATTER

The subject matter is organized into eleven Topics in the software program: *The Bigger Picture*, *Precipitation*, *Water in Soil*, *Infiltration*, *Evaporation and Transpiration*, *Runoff*, *Watershed Hydrology*, *Groundwater*, *Water Quality*, *Mechanical Properties of Soil*, and *Soil Quality and Land Degradation*. Although non-linear browsing is an option within the program, inevitably, a deeper understanding of concepts requires hierarchical learning, and the Topics are ordered such that earlier Topics are helpful in the understanding of later Topics. A brief description of each Topic follows.

The Bigger Picture presents just three Subtopics: *Soil Functions*, *Water Partitioning*, and *Soil Water Budget*. They are meant to give a simple overview of soil and water management while introducing some terminology, and answer the following basic questions: What is Soil? How does water interact with the soil - what happens when it can or cannot infiltrate? In what ways may their interaction affect soil and water quality over time? What is a soil water budget?

Precipitation is another brief Topic including three Subtopics. It introduces many definitions relevant to the characterization of precipitation (in general as well as for a given locale), and discusses the relationship between precipitation and the potential for erosion on a given soil.

Water in Soil covers 30 Subtopics important to the understanding of the behavior of water in soil. The first Subtopic introduces the various phases (gas, liquid, and solid) included in soil, of which water is a significant component mainly comprising the liquid phase. Subsequent Subtopics discuss the various characteristics and properties of water, the concept of water potential, and how water in soil moves.

Infiltration first presents a Subtopic reviewing the Soil Water Budget, of which infiltration represents inputs to soil water, and therefore affects water available for

plants, soil storage, or further subsurface movement laterally (interflow) or deeper into the profile (percolation). Subsequent Subtopics discuss various factors which influence infiltration.

Evaporation and Transpiration includes, in three Subtopics, basic terminology for various types of evaporation and transpiration measurements, and discussions of the significance of transpiration on soil water conditions and of evapotranspiration on the water budget throughout the year.

Runoff covers runoff terminology, hydrograph interpretation, factors influencing runoff, and estimation of runoff rate and volume.

Watershed Hydrology describes water movement at the watershed scale and how they are affected by specific characteristics such as slope and catchment area. Factors relevant to management and prevention of pollution at the watershed level are also discussed.

Groundwater introduces some relevant geologic terminology and describes groundwater movement.

Water Quality discusses various types of environmental pollution to ground and surface waters, including pathogens, pesticides, and nutrients. Environmental standards and specific case studies are also discussed.

Mechanical Properties of Soil describes the physical properties of soil within the context of their management and vulnerability to environmental and management factors.

Soil Quality and Land Degradation discusses ecological indicators of soil quality, and management issues such as erosion, conservation, tillage, and alternative cropping systems.

PROJECT DESCRIPTION: DESIGN DEVELOPMENT

The interface and functional elements of the program were the sole and original creation of the author. This section will discuss influences upon and purposes of the program design.

Display Interface

The author designed the general appearance of the screens with several specific goals in mind. Because a User feels best about a program in which he or she feels “in control,” the author realized several priorities: to make it clear where the User is, to make the program as intuitive and pleasant to use as possible, and to make it easy to navigate from one area of the program to another. At the same time, the design was influenced by the basic nature and purpose (college-level, educational) of the program itself. Because of its educational nature, it was designed to maximize the area in which informational content is viewed, which required economy in the design of the interface.

The consistent placement of the interface elements was intended to make their use intuitive, easy to remember, and minimally demanding mentally or physically. Labels at the top of the screen, including the CD title, the Topic, and Subtopic titles, were designed to be compact while clearly informing the User where he or she is at any time. The dual-function sidebar at the right-hand side of the screen is compact, and its location near the other controls (page scrollbar, back/previous buttons) eliminates any unnecessary moving of the mouse back-and-forth across the screen, thus minimizing physical distractions or demands upon the User.

Navigational Design

The challenge in a primarily informational piece is to allocate as much room as possible to the informational content while still having an easy-to-use interface that allows for many buttons (and therefore greater accessibility to other pages and/or features). A very simple and intuitive interface can consist of only two buttons, but then that may require the User to navigate through a long series of pages or layers of menus to in order to get from one section to another. In contrast, in this program, much deliberate attention was given in making the non-informational parts of the screen spatially economical, yet extremely functional – allowing the User many options without requiring extensive effort. For example, the Subtopics Menu was created to be scrollable, so while only displaying seven on screen, it can actually contain up to 30 subtopics which the User may easily view without losing his or her place. Likewise, the Subtopics Panel and Accessories Panel are always available, but the User chooses which to make active (the other becomes hidden) at any time by simply clicking on one or the other.

In general, the design goals were to save space in the creation of a user-friendly, multi-functional interface.

PROJECT DESCRIPTION: CREATION AND INTEGRATION OF MULTIMEDIA

Images

Images were created in Photoshop, Illustrator, and Director software. Certain other images were provided to the author in digital form, although most of these were further edited by the author.

The photographic images from the Topic cover pages (also featured in the *Splash Page*) were photos (either taken with slide or regular 35-mm film) which were scanned on a scanner and then digitally color-corrected in Photoshop. Some of these photos were taken and scanned by the author (such as the photos for “Evaporation and Transpiration”), some were only scanned by the author (“Precipitation”), while others (generally already in digital form) came from other sources as noted in the Photo List page.

Illustrations

As with the photographs, some digital images were provided to the author for insertion into the program. These were reviewed and edited by the author as deemed appropriate, and as time permitted. Many illustrations are yet to be revised, and many more are to be created for inclusion in the future further development of the project.

If an illustration was not changed substantially, it is credited to the original creator with the image whenever it is displayed within the software. If it was altered by the author substantially, it is dually credited to the author and the original creator. Illustrations created by the author alone are credited accordingly. All credits are clearly displayed with the images themselves within the software.

Animations

All animations were created by the author. Examples include “Partitioning Water Flow” within “The Bigger Picture,” and “Pressure Potential” in “Water in Soil.” Generally the animations were comprised of several images originally drawn in Illustrator, then imported individually into Director within which they were sequenced. Illustrator tools such as the “Blend” feature were essential in the creation of intermediate steps between a beginning and ending image. The “Blend” feature was also used to create color gradients following a specific form. EPS Publisher files were created for the export of the Illustrator files as bitmaps; these Publisher files were opened independently, copied onto the Clipboard, and then pasted into the Director cast into as new, individual cast members.

In several instances, embellishments were made within Director to images and/or animation frames, particularly such things as the addition of arrows and text which could be easily added, edited, and standardized within Director.

PROJECT DESCRIPTION: STRUCTURAL OVERVIEW

The four main areas of the program are: *Splash Page*, *Main Menu*, *Topic/Subtopic pages*, and *Accessories Pages*.

Splash Page

The *Splash Page* displays a series of eleven photos that are each found within the main program on their corresponding Topic cover pages (Figs 2-4). When the display sequence is complete, the User is brought automatically to the *Main Menu*. Clicking on the screen or pressing any key before the splash presentation is over will abort the splash presentation and bring the User immediately to the *Main Menu*.

Main Menu

The *Main Menu* provides the User direct access to menus for each section of the program, including Topics, Subtopics and Accessories (Fig. 5). It displays a list of all Topic titles with thumbnails of photos associated with each; clicking on either the Topic titles or thumbnails will bring the User to that *Topic Cover Page*, which features its theme photograph and maintains access to that Topic's Subtopics. In addition, the *Main Menu* page displays, and allows simultaneous access to Subtopics for every Topic via the *Subtopic Panel*, which displays the Subtopic titles that correspond to the currently highlighted Topic selected by User mouse rollover. Similarly, the *Main Menu* page also displays, and allows simultaneous access to Accessories via the *Accessories Panel*, a menu display which somewhat overlaps with, and, by default is mostly hidden by the *Subtopic Panel* except when the User activates the *Accessories Panel*. The *Accessories Panel* and *Subtopic Panel* were designed to fit in the same space for efficiency; the User can easily toggle between the two Panels at any time by clicking on the appropriate tabs.

Topics/Subtopic Pages

Topics include a *Cover Page* and *Subtopic Pages*. Each cover page includes a photo descriptive of the *Topic*, *Next(Page)/Previous(Topic) Buttons*, and *Subtopics/Accessories Panel* (Fig 6). *Subtopic pages* include Subtopic title, text, and graphics, *Page Scrollbar* when appropriate, *Next(Page)/Previous(Topic) Buttons*, and *Subtopics/Accessories Panel*. The *Page Scrollbar* is similar in look, feel, and function to standard operating-system scrollbars; it allows the User to scroll the page up or down in order to view off-screen text and/or graphics.

Accessories Pages

The *Accessories Pages*, which are accessed through the *Accessories Panel*, include *Print Topics*, *Units*, *Glossary*, *Photo List*, *Video List*, *Web Links*, *Version Info*, *About*, *User Hints*, and *Credits*. However, only select *Accessories Pages* are complete at this current time, so although the *Accessories Panel* links will bring you to the corresponding *Accessories Page*, that page may be incomplete at this stage. Completed *Accessories Pages* include *Print Topics*, *Photo List*, *About*, *User Hints*, and *Credits*. *Print Topics* is a feature that allows the user to select one or more *Topics* to print; it includes a print preview feature. *Photo List*, *About*, *User Hints*, and *Credits* are single-screen informational pages only. Possibilities for the further development of the *Accessories Pages* are discussed in below (see Discussion).

PROJECT DESCRIPTION: NAVIGATIONAL DEVICES

There are many navigational devices in the program, including menus, clickable arrows, key commands, and various specialized buttons.

Subtopics Panel

The *Subtopics Panel* has several unique functions and features.

View-and-browse and *Direct access to Subtopics* are the main functions of the *Subtopics Panel*. Within a given Topic, the *Subtopics Panel* displays all Subtopic titles for that Topic only. Within the Main Menu, a list of corresponding Subtopic titles are displayed for any Topic highlighted. (A Topic is highlighted whenever the User rolls the mouse over its title or thumbnail.) Thus, the User may easily view and browse Subtopic titles corresponding to the current Topic at any time, and from the Main Menu, can view all Subtopic titles of all Topics without leaving the page.

In addition, Subtopic titles displayed within the *Subtopics Panel* are all clickable; if any is clicked, the User will be brought directly to that Subtopic, whether from within the given Topic or from the Main Menu.

The various features programmed into the *Subtopic Panel* include the *Scrollable Menu* and *Subtopics Counter*. Because the number of Subtopics greatly varies among Topics (from 3 to 30), and the designated screen area limits the display to seven subtopic titles at a time, the subtopics panel was programmed to be scrollable when appropriate. Whenever more than seven subtopics comprise the current Topic, the *Subtopics Panel* automatically becomes scrollable, evident by the appearance of up and down arrows on its top and bottom margins. The User clicks on Up and Down Arrows to scroll the menu; the arrows light up when clicked, and may be held down for continuous scrolling or tapped repeatedly for unit scrolling. When the menu is either

scrolled all the way to the top or bottom of the Subtopics list, the corresponding Up or Down arrow grays-out to indicate that the menu cannot be scrolled any further in that direction.

The *Subtopics Counter* indicates total number of subtopics for the given Topic.

Accessories Panel

The *Accessories Panel* includes access to various features/pages such as User Hints, Print Topic, Credits, Web Links. Three of the Accessories (About, User Hints, and Credits) extends beyond the Subtopics Panel, allowing those Accessories to be clicked directly at any time. The User activates the full *Accessories Panel* by clicking on its title/tab. Once activated, *Accessories Panel* choices are brought in front of the Subtopics for display. The User may toggle between Subtopics and Accessories display at any time by clicking on their respective Tabs.

Back Button

The *Back Button* appears only within the Accessories Pages. If the User originally opens an Accessory Page from a Topic or Subtopic Page, the *Back Button* will return the User to that same Topic or Subtopic. Otherwise, the User is returned to the Main Menu.

Next/Previous Buttons

The *Next/Previous Buttons* are found in the bottom right-hand corner of the screen, and appear throughout every Topic, including cover page and all subtopics pages. However, they appear in three slightly different formats. The Cover Page *Next/Previous Buttons* allow the User to either continue to the first Subtopic, or jump backwards to

the beginning of the previous Topic. Beginning with the First Subtopic, the *Next/Previous Buttons* allow the User to either continue to the next Subtopic, or page backwards to previous Subtopic. The last Subtopic's *Next/Previous Buttons* allow the User to either continue to the next Topic, or page backwards to previous Subtopic. Rollover "Tool Tips" plus the different appearance of the buttons according to their functions indicate to the User these changes in function of the *Next/Previous Buttons*.

Keyboard Commands

Keyboard Commands are not listed formally in the program for the User's information, but are available. The *left and right arrow keys* page forward and backward in a manner corresponding to the *Next/Previous Buttons*. *Up and down arrows* will scroll the page up and down when the *Page Scrollbar* is present.

PROJECT DESCRIPTION: GRAPHICS, ANIMATIONS, AND INTERACTIVE TEACHING ELEMENTS

Various graphical and interactive elements were incorporated into certain parts of the program as a demonstration of how they may be employed (1) to maintain or stimulate interest of the User and (2) as teaching devices. Described below are the types of graphical and interactive elements used, and examples of each as found within the program.

Graphics

Graphics in the program are typically (1) based on photos, (2) based on imagination, (3) schematics, or (4) graphs. For example, the image of a soil profile found in the Soil and Water Subtopic “Gravitational Potential” (Fig. 7) was constructed from a manipulated and enlarged photo image taken previously. Other images in Water in Soil, such as those including water droplets or molecules (“Molecular Forces Affecting Soil Water” (Fig. 8) and “Surface Tension” (Fig. 9)), are more clearly presented as illustrations rather than photographs. Finally, there are schematics, such as the graphic in “The Capillary Tube Analogy” (Fig. 10), and graphs, as in “Effect of Compaction...(on the Soil Water Characteristic Curve)” (Fig. 11).

Animations

Animations are based on the above types of graphics, sequenced appropriately to convey a process occurring over time. (1) “Pressure Potential” (Fig. 12) displays the soil profile first presented in “Gravitational Potential (Fig. 7)” but shows it as an animation of that soil profile drying out. Symbols for relative water potential move with the drying front during the animation to demonstrate the potentials that correspond

with a changing soil profile's water contents. (2) In “Molecular Forces Affecting Soil Water” (Fig. 8) water molecules have been animated to suggest their polarity and resulting tendencies to form weak bonds to other water molecules and to soil particles. (3) The graphic in “The Capillary Tube Analogy” (Fig. 10) is not animated, but it could be made into an animation which depicts the relationship between capillary radius and height of water – these could be shown changing in direct proportion to one another. (4) The graph in “Effect of Compaction... (on the Soil Water Characteristic Curve)” (Fig. 11) is animated, showing change over time in the Soil Water Characteristic Curve as an aggregated soil becomes compacted.

Interactive Elements

Interactive elements, which often include graphics or animations, involve user-controlled inputs that change the resulting display. At the most passive level, for example, the User controls navigation. Similarly, the User can pause/continue, replay, and step to the next animation using the Animation Remote Control. In contrast to simple navigational devices, *interactive teaching elements* involve the User, in activities directly relevant to the subject material. The graph in “Soil Water Characteristic Curve” (Fig. 13) is an interactive graph which allows the user to input different soil textures by means of a slider, and view the resulting changes in the relationship between soil water content and soil water potential.

PROJECT DESCRIPTION: MISCELLANEOUS FEATURES

Currently Discontinued Features

Two features, *Reveal-on-Rollover* and *Subtopic Text Compiler and Printer* described below were originally programmed but are not included in the current thesis project. *Reveal-on-Rollover* was discontinued because of its excessive labor and memory-intensive requirements, especially in an evolving piece. A alternative approach in scripting may enable more efficient handling of the same feature in the future. The *Subtopic Text Compiler and Printer* feature was discontinued because, although very memory-efficient, the loss of text-formatting which could not be prevented was deemed unacceptable.

Reveal-on-Rollover

A *Reveal-on-Rollover* option allowed the User to control the appearance of the Subtopic pages. When this option was selected, Subtopics Pages by default displayed all text and images faintly until the User passed the mouse over sections of it. As the mouse rolled over paragraphs of text and graphics, they would instantly darken to normal visibility. This feature was intended for classroom presentation purposes, particularly for screen projection, as it would allow a lecturer to gradually display the screen text. In addition, if the User clicked on any single paragraph or graphic, all text and graphics would fade except that text or graphic, which would display normally, so the User could either continually reveal more and more of the screen, or could sequentially reveal and hide sections at will.

Subtopic Text Compiler and Printer

User-selected subtopic pages could be marked at any time during program use for future compilation of its text into a text file or print document which could be spooled directly from the program. Any number and combination of subtopics could be selected for this purpose, and as the subtopics were chosen, a counter indicated how many subtopics had been chosen so far. In addition, the subtopic titles within the Subtopics Panel would change to a dark purple to indicate they were marked for this purpose. Under this option, there was also a print preview option. Text formats, including variations in line spacing and font changes (including Greek symbols used in mathematical expressions), however, could not be retained, nor could any graphics be included in this feature since all were converted to plain text. Printing alternatives are discussed below in the section entitled *Future Development: Possibilities in Printing From Director*.

Features Temporarily Incorporated for Gallery Display Purposes

In addition, certain other features were programmed for gallery exhibition purposes only, and are not to be retained “as is” for future proposed classroom usage. These included the automatic return to *Splash Page* after two minutes of inactivity, and the “Tool-Tip” rollovers on the *Next/Previous Buttons*. These features might be retained if an option for the User to turn them off is added.

PROJECT DESCRIPTION: FUTURE DEVELOPMENT

Further development of the project is planned for the immediate future. Some of the possible future modifications and additions are described below.

Possibilities in Printing From Director

One of several possible alternative methods for printing was chosen to replace the *Subtopic Text Compiler and Printer* feature, namely, printing via the use of the Print-O-Matic Lite Xtra. The Print-O-Matic Lite Xtra allows printing of any individual cast member(s), including text, image, or field cast members. The limitation is that the Xtra can only print the cast member “as is”— 72 ppi, which will translate by default into 72 dpi – unless the cast member is a text field, in which the text will print as true text, and is therefore good print-quality. Within Director, all Text cast members (*not* to be confused with text *field* cast members) and images are all 72 ppi. Text and image can be included together in a single cast member only when combined into an image (bitmap), thus again will print by default at 72 dpi.

However, because a built-in feature of Print-O-Matic Lite is its automatic scaling-down of cast members to fit a page, it is possible to increase the print resolution by creating cast members with dimensions larger than the equivalent of the printed page at 72 dpi. For example, if a image cast member’s dimensions were 1220x1650 pixels, or roughly twice the size of an 8.5 x 11” page at 72 dpi (600x800 pixels), then the Xtra would automatically scale the image to fit the page, printing at a 50% reduction, and resulting in approximately a 150–dpi printout. The drawbacks to this process are the somewhat complicated planning needed to design the oversized 72 ppi-pages (if the printing reductions and concomitant dpi increases are the desired result), and the

resulting amount of memory these oversized images will necessarily occupy within the Director cast. Unfortunately, the text quality is still compromised because it is still just a bitmapped low-resolution conversion from true text, even with the effective dpi increases.

Portable Document Format (PDF), created by Adobe, appears to be the best solution to the general problem of having text and image combined in memory-efficient, yet print-quality files that are ready to view on-screen. However, Director is not directly compatible with PDF. Director (version 7.02) cannot directly read or import PDF. There is an Active-X Xtra which does allow for viewing and even creation of many external document formats including web, spreadsheet, and PDF files, but it is only available for Director for Windows. No analogous Xtra is available for the Macintosh version of Director.

For web-savvy and technologically up-to-date audiences, there is an answer that is perhaps more satisfactory. Director *can* launch a web browser, and if the web browser is equipped with the Adobe Acrobat Plug-In, the User may view and print PDF files via that web browser. However, the use of the browser is necessarily external to Director; viewing of the web and/or PDF cannot be made internal. The drawbacks are: the requirement of the installation of a web browser with the Acrobat Plug-in on the User's system, the extra memory (RAM) demands caused by both applications running simultaneously, and the sophistication required of the User in navigating between two applications.

Because the project is meant for the broadest audience possible, it is not assumed that Users will necessarily have Internet access, recent-model computers, or heavy experience with computer applications in general, and therefore further alternatives are still being explored regarding the print function. Ideally, the User will

not have to use applications external to Director (or the Director projector file) to print, yet the print document will be memory efficient and print true-text as in PDF. Ongoing research to determine whether a proprietary Xtra that can do this exists, or if perhaps one may be authored in the future.

Further Customizability of the Accessories Panel

Another possible feature to be incorporated is the further customizability of the Accessories Panel in which the Accessories Panel Buttons would be made mobile. The User would be able to reposition the Accessories Panel Buttons within the Panel, including those that remain visible when the Subtopics Panel is active (currently “About,” “User Hints,” and “Credits”). Thus the interface would become even more convenient to the User with this ability to place the most often-used Buttons where always accessible.

General

In general, more graphics, animations, and interactivity are planned. The websites will be hotlinked. More illustrations and interactivity will be incorporated. Possibly, more types of media, such as sound and video, will also be added.

SUMMARY AND CONCLUSION

The accompanying CD-ROM contains the thesis project described in detail above. Entitled "The Cornell University Soil and Water Learning Module," it is designed to accompany an actual college-level course taught at Cornell University.

Authored in Director® 6.5®, it includes text, photos, graphics, animations, and interactive components through its design. Major advantages to using Director® software include the ability to create self-running cross-platform products which can be entirely customized via Lingo programming to include a vast array of interactive media, including text, sound, images, animations, and three-dimensional models.

Further development of the project is planned for the immediate future. Planned are: Several features to be revised or newly included, the inclusion of many new graphics and animations, and the completion of the Accessories Pages, including hot links to websites.

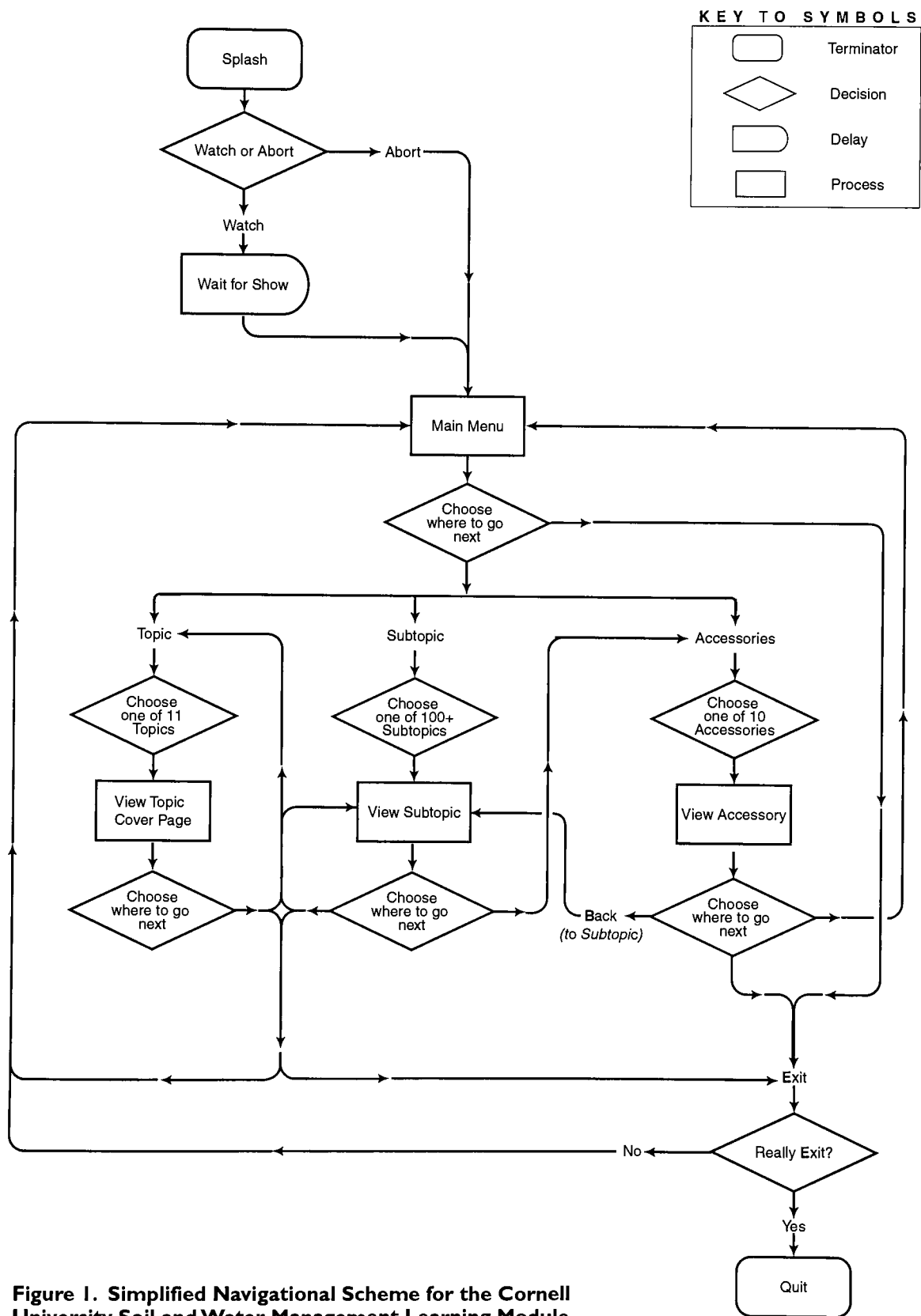


Figure 1. Simplified Navigational Scheme for the Cornell University Soil and Water Management Learning Module.



Figure 2 (top). "The Bigger Picture" theme photo from the Splash Page.

Figure 3 (middle). The "Infiltration" theme photo from the Splash Page.

Figure 4 (bottom). The "Evaporation and Transpiration" theme photo from the Splash Page.

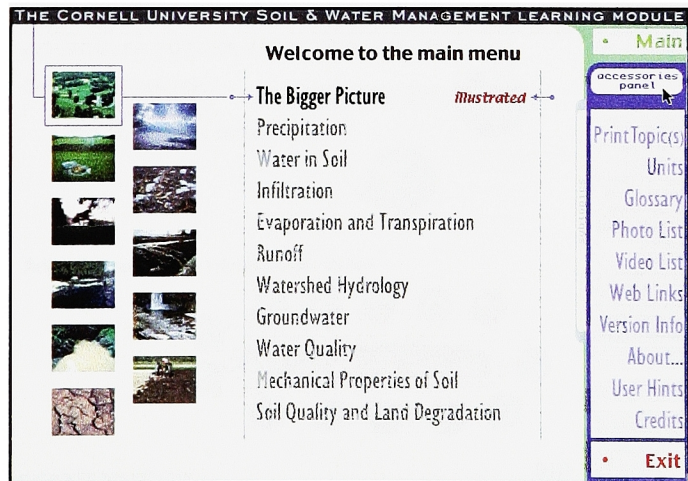
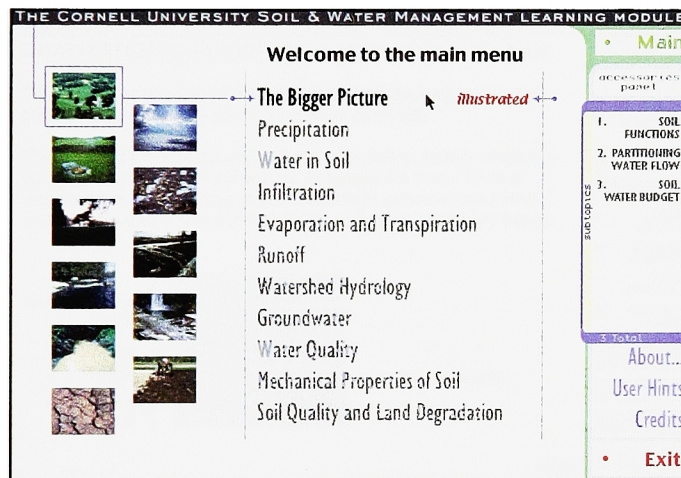
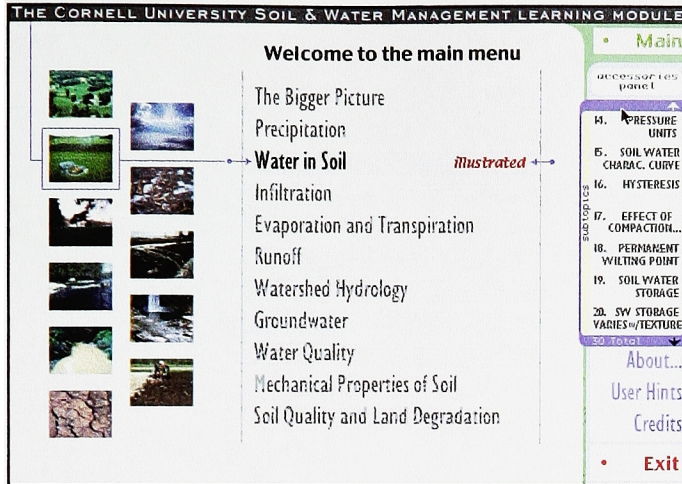


Figure 5. Three screen shots from the Main Menu.

Top: The Subtopics Panel with its scrollability feature active.

Middle: The Subtopics Panel with its scrollability feature inactive.

Bottom: The Accessories Panel is active instead of the Subtopics Panel.

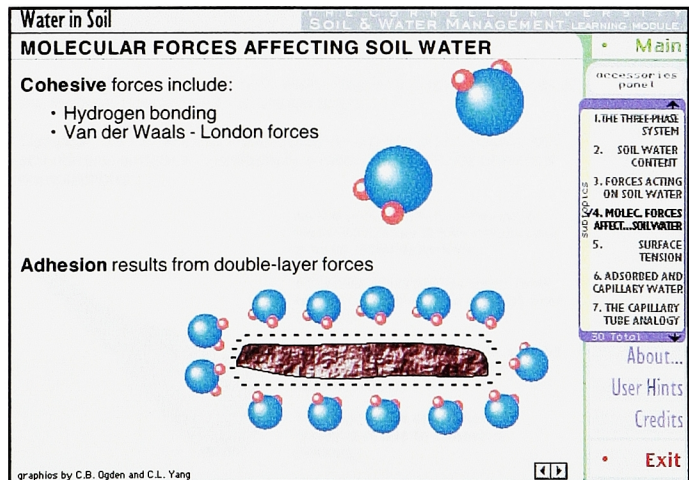
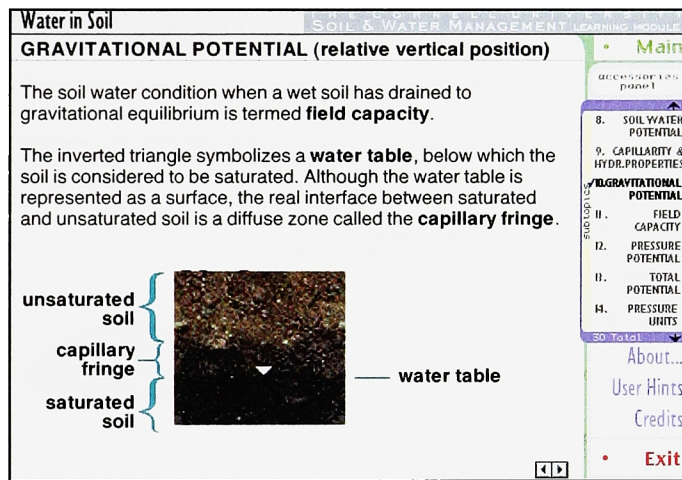
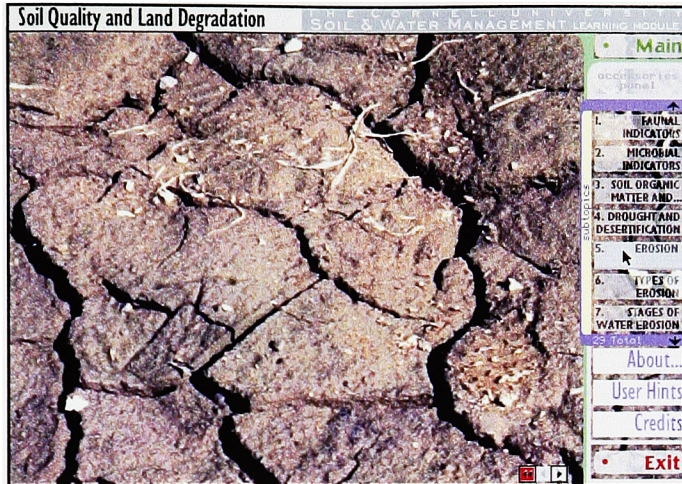



Figure 6 (top). The Topic Cover Page from the Topic “Soil Quality and Land Degradation.”
 Figure 7 (middle). A screen shot from the Subtopic “Gravitational Potential.”
 Figure 8 (bottom). A screen shot from the Subtopic “Molecular Forces Affecting Soil Water.”

Water in Soil SOIL & WATER MANAGEMENT LEARNING MODULE

SURFACE TENSION

Water tends to minimize the air-water interface. Water molecules at the surface experience a net inward force.

Consider the behavior of water drops on a glass plate. (Glass and soil mineral particles – particularly quartz – have similar chemical compositions.)



Without gravity, and neglecting adhesion to the glass plate, a volume of water forms a sphere due to internal cohesion and surface tension.

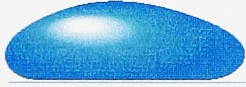
Main
 accessories panel
 1. THE THREE-PHASE SYSTEM
 2. SOIL WATER CONTENT
 3. FORCES ACTING ON SOIL WATER
 4. MOLEC. FORCES AFFECT...SOILWATER
 5. SURFACE TENSION
 6. ADSORBED AND CAPILLARY WATER
 7. THE CAPILLARY TUBE ANALOGY
 80 Total
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Water in Soil SOIL & WATER MANAGEMENT LEARNING MODULE

SURFACE TENSION

Water tends to minimize the air-water interface. Water molecules at the surface experience a net inward force.

Consider the behavior of water drops on a glass plate. (Glass and soil mineral particles – particularly quartz – have similar chemical compositions.)



Gravity and adhesion distort the sphere into roughly a hemisphere.

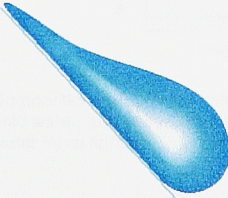
Main
 accessories panel
 1. THE THREE-PHASE SYSTEM
 2. SOIL WATER CONTENT
 3. FORCES ACTING ON SOIL WATER
 4. MOLEC. FORCES AFFECT...SOILWATER
 5. SURFACE TENSION
 6. ADSORBED AND CAPILLARY WATER
 7. THE CAPILLARY TUBE ANALOGY
 80 Total
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Water in Soil SOIL & WATER MANAGEMENT LEARNING MODULE

SURFACE TENSION

Water tends to minimize the air-water interface. Water molecules at the surface experience a net inward force.

Consider the behavior of water drops on a glass plate. (Glass and soil mineral particles – particularly quartz – have similar chemical compositions.)



As the plate is tilted, cohesion or viscosity causes the hemispherical drop to resist distortion.

Adhesion prevents the water from sliding (in response to gravity) over the plate.

As the plate is tilted further, gravity overcomes viscosity and the drop begins to flow.

The "tail" of the characteristic teardrop is due to adhesion (wetting).

Main
 accessories panel
 1. THE THREE-PHASE SYSTEM
 2. SOIL WATER CONTENT
 3. FORCES ACTING ON SOIL WATER
 4. MOLEC. FORCES AFFECT...SOILWATER
 5. SURFACE TENSION
 6. ADSORBED AND CAPILLARY WATER
 7. THE CAPILLARY TUBE ANALOGY
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Figure 9. Three sequential screen shots from the Subtopic “Surface Tension.” Animations depict the changes in the shape of a water droplet under various hypothetical conditions.

Water in Soil SOIL & WATER MANAGEMENT LEARNING MODULE

THE CAPILLARY TUBE ANALOGY

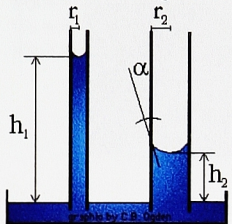
Soil can be regarded as a set of interconnected capillary tubes able to hold water at a given suction (negative pressure; matric potential) depending upon the radius of the tube.

The pressure potential due to a capillary of radius r is equivalent to the weight of (i.e. "force of gravity" on) the water column of length h .

$$h = (2\gamma \cos\alpha / r)$$

where γ is the surface tension constant and it is generally assumed that $\cos\alpha = 1$

In millimeters, $h = 15/r$.

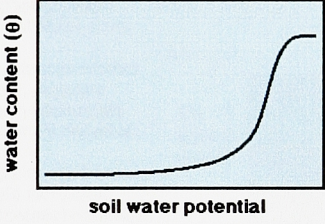


It is convenient to express soil water potentials in terms of the height of rise "h." This relationship is actually observed in capillary tubes - the smaller the radius, the higher the water rises within it.

Main
accessories panel
4. MOLEC. FORCES ATTRACT...SOILWATER
5. SURFACE TENSION
6. ADSORBED AND CAPILLARY WATER
7. THE CAPILLARY TUBE ANALOGY
8. SOIL WATER POTENTIAL
9. CAPILLARITY & HYDR.PROPERTIES
GRAVITATIONAL POTENTIAL
50 Total
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Water in Soil SOIL & WATER MANAGEMENT LEARNING MODULE

EFFECT OF COMPACTION on the SW characteristic curve

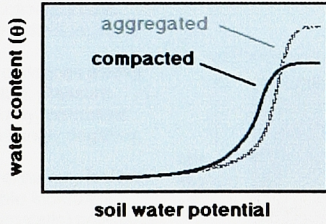


Compaction reduces the volume of large pores and their loosely held water, and increases the volume of smaller pores which hold water more tightly.

Main
accessories panel
14. PRESSURE UNITS
15. SOIL WATER CHARAC. CURVE
16. HYSTERESIS
17. EFFECT OF COMPACTION...
18. PERMANENT WILTING POINT
19. SOIL WATER STORAGE
20. SW STORAGE VARIES w/TEXTURE
50 Total
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Credits
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Water in Soil SOIL & WATER MANAGEMENT LEARNING MODULE

EFFECT OF COMPACTION on the SW characteristic curve



Compaction reduces the volume of large pores and their loosely held water, and increases the volume of smaller pores which hold water more tightly.

Main
accessories panel
14. PRESSURE UNITS
15. SOIL WATER CHARAC. CURVE
16. HYSTERESIS
17. EFFECT OF COMPACTION...
18. PERMANENT WILTING POINT
19. SOIL WATER STORAGE
20. SW STORAGE VARIES w/TEXTURE
50 Total
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Figure 10 (top). A screen shot from the Subtopic "The Capillary Tube Analogy."
Figure 11 (middle and bottom). Sequential screen shots from the Subtopic "Effect of Compaction on the Soil Water Characteristic Curve."

Water in Soil

SOIL & WATER MANAGEMENT LEARNING MODULE


PRESSURE POTENTIAL (dryness; hydrostatic pressure)

At the water table, the pressure potential (phreatic surface) is, by definition, zero.

At increasing distances **above the water table**, pressure (matric; capillarity) potentials become increasingly negative.

At increasing distances **below the water table** increases, pressure (hydrostatic) potentials become increasingly positive due to the weight of overlying water. Note that this is the opposite of the situation with gravitational potential, which is increasingly positive with height.

$\psi_p < 0$
 $\psi_p = 0$
 $\psi_p > 0$



Main

accessories panel

9. CAPILLARITY & HYDR. PROPERTIES

10. GRAVITATIONAL POTENTIAL

11. FIELD CAPACITY

12. **PRESSURE POTENTIAL**

13. TOTAL POTENTIAL

14. PRESSURE UNITS

15. SOIL WATER CHARAC. CURVE

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Water in Soil

SOIL & WATER MANAGEMENT LEARNING MODULE

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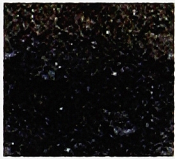
At increasing distances **below the water table** increases, pressure (hydrostatic) potentials become increasingly positive due to the weight of overlying water. Note that this is the opposite of the situation with gravitational potential, which is increasingly positive with height.

$\psi_p < 0$ above water table

$\psi_p = 0$

$\psi_p > 0$

$\psi_p > 0$ below water table



Main

accessories panel

9. CAPILLARITY & HYDR. PROPERTIES

10. GRAVITATIONAL POTENTIAL

11. FIELD CAPACITY

12. **PRESSURE POTENTIAL**

13. TOTAL POTENTIAL

14. PRESSURE UNITS

15. SOIL WATER CHARAC. CURVE

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Water in Soil

SOIL & WATER MANAGEMENT LEARNING MODULE

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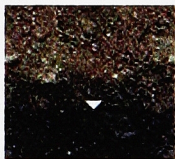
$\psi_p \ll 0$ above water table

$\psi_p < 0$

$\psi_p = 0$

$\psi_p > 0$

$\psi_p \gg 0$ below water table



Main

accessories panel

9. CAPILLARITY & HYDR. PROPERTIES

10. GRAVITATIONAL POTENTIAL

11. FIELD CAPACITY

12. **PRESSURE POTENTIAL**

13. TOTAL POTENTIAL

14. PRESSURE UNITS

15. SOIL WATER CHARAC. CURVE

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Figure 12. Three sequential screen shots from the Subtopic "Pressure Potential."

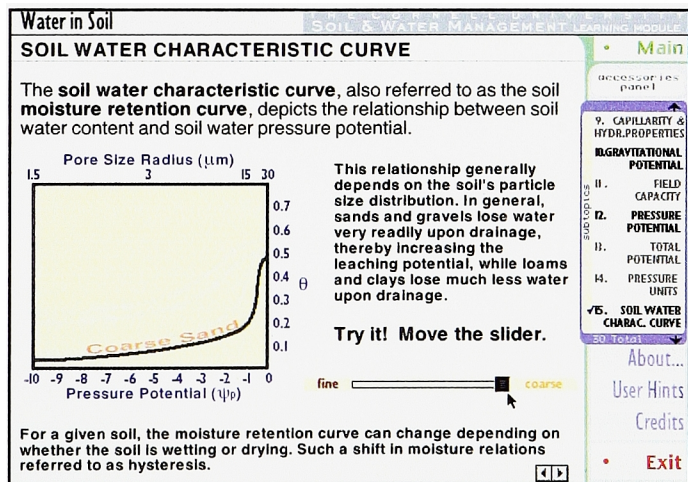
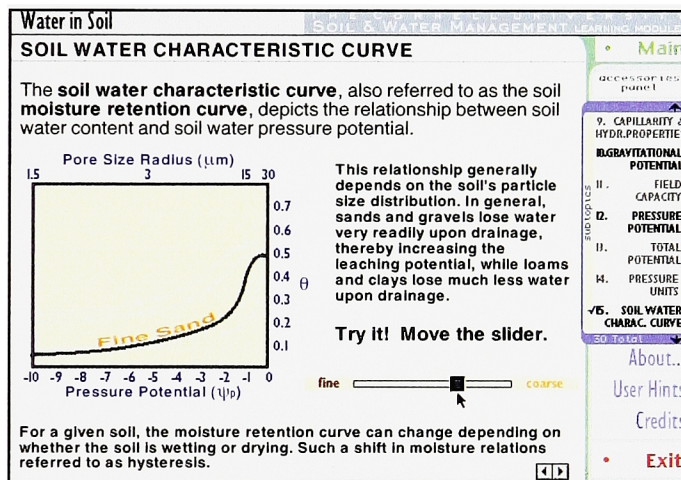
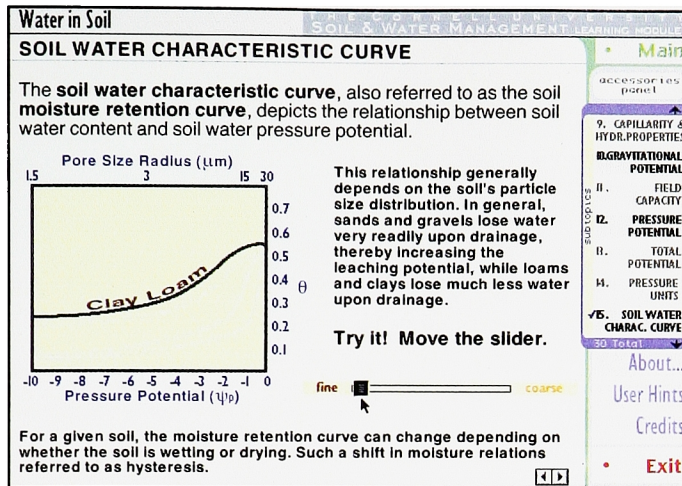



Figure 13. Three different screen shots from the Subtopic “Soil Water Characteristic Curve.” The graph changes interactively as the User moves the slider.

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Soil and Water Management
Learning Module**

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